AS Unit 1: Basic Biochemistry and Cell Organisation

Name:	Date:

<u>Topic 1.5 Nucleic Acids and their functions</u> – Page 2

I. Nucleic Acids and their Functions DNA and RNA

		Completed
1.	Go through the PowerPoint and read the notes and fill in the blanks pages 2-7	
2.	Complete the review quiz on page 8	
3.	Complete the worksheet p9-10 on Nucleic Acids	
4.	Read the extra handouts page 11-12	
5.	Practice the past paper questions p13-15	

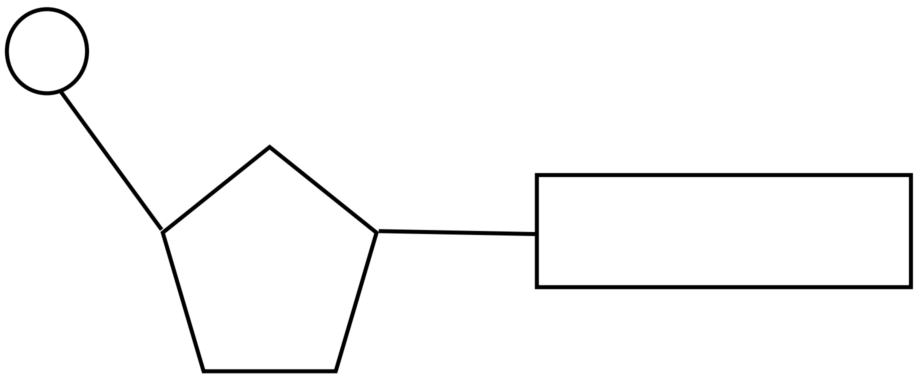
Nucleic Acids

A **nucleotide** is the basic unit or monomer from which nucleic acids are formed. Nucleic acids have the ability to store information that controls cell activity and are involved in the transmission of genetic material.

The three shapes shown by each of the parts are usually used when drawing a simple diagram of DNA or RNA structure.

The deoxyribose sugar, phosphate group and organic base are joined together as shown below to form a nucleotide.

A DNA nucleotide.

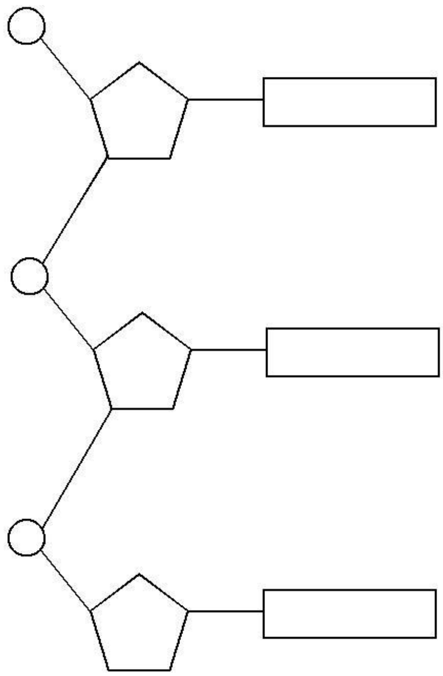


Label the three parts of the DNA nucleotide shown above.
All DNA nucleotides contain a phosphate group, deoxyribose sugar and organic base **but** they do not all have the same base. Four different bases are found **adenine**, **thymine**, **cytosine** and **guanine**.
The names of these four bases are usually abbreviated to the letters A, T, C and G. These 4 letters form the bases of the genetic code.
Pick one of the four bases and draw a nucleotide (using the shapes as described above) with that base attached in the box below:

DNA nucleotides can be joined together to from a polymer, a polynucleotide.

This reaction produces water and is known as a ___________________________ reaction.

Below is a simple diagram showing the polynucleotide structure of a single strand of DNA.



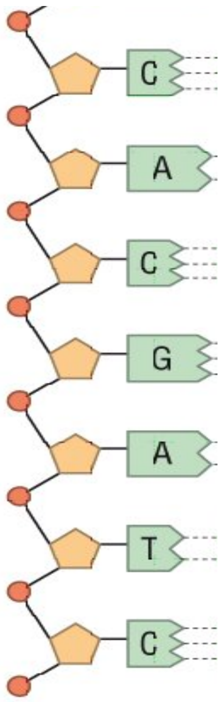
Between which 2 parts of the nucleotides (monomers) have bonds been made in order to form a polymer molecule?

____

A covalent bond forms between these 2 parts. What does a covalent bond mean?

____

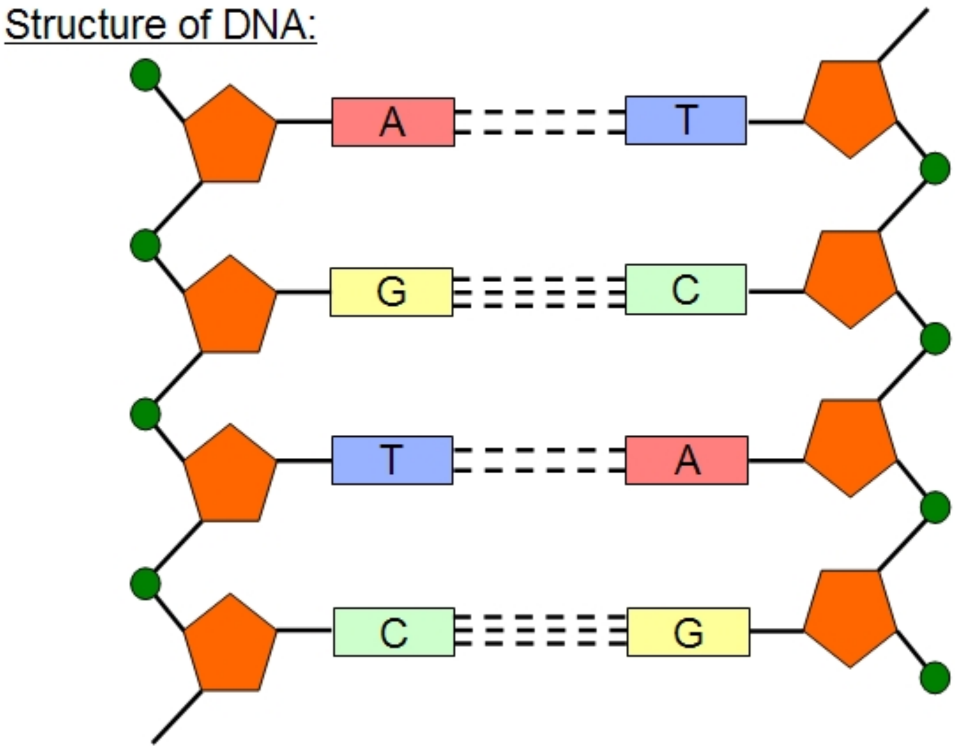
Label all the parts on the diagram where there is a covalent bond.



We describe the structure as having a 'sugar-phosphate backbone'. This sugar phosphate backbone is very strong, it is a lot easier to break the hydrogen bonds holding the base pairs together in DNA, than it is the bonds between the sugar and phosphate group.

The structure of DNA is in fact a 'double helix', with two strands of polynucleotides (polymers of nucleotides) antiparallel to one another (one runs in one direction and the other in the opposite direction), these two strands are then twisted to form a helix. The two strands are held together by hydrogen bonds that form between the organic nitrogen containing bases. This creates an effect that looks like a ladder.

Hydrogen bonds can only form between adenine and thymine; and between guanine and cytosine.
This is known as **complimentary base pairing**.



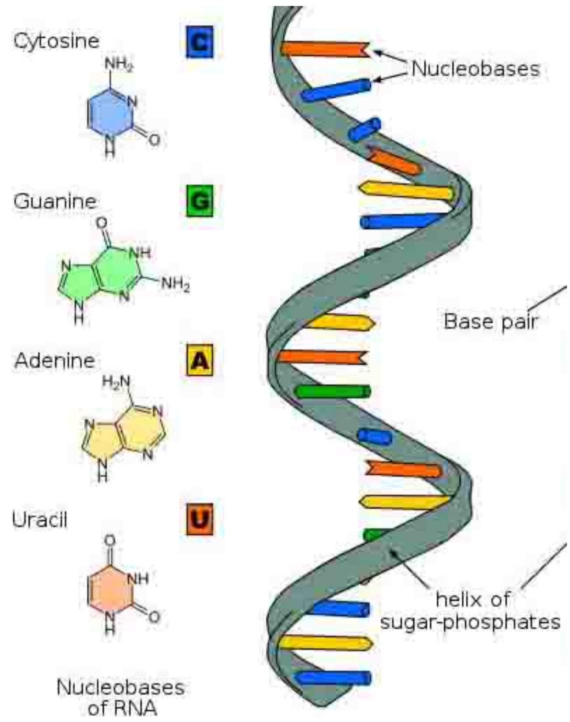
On the diagram above label the following;

- A deoxyribose sugar.
- A nitrogenous base.
- A hydrogen bond.
- The sugar-phosphate backbone.

DNA has **two major functions** – it needs to be replicated during the S stage of interphase in preparation for mitosis or meiosis **and** contains genes, genes contain the information for synthesizing proteins.

RNA.

Cells also contain another polynucleotide called RNA (Ribonucleic acid). It has a number of similarities and a number of differences with DNA. Look at the diagram to the right and see if you can list some of the similarities and differences in the table below.

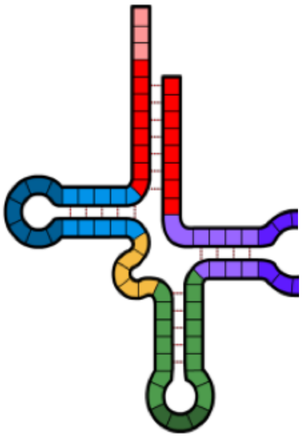


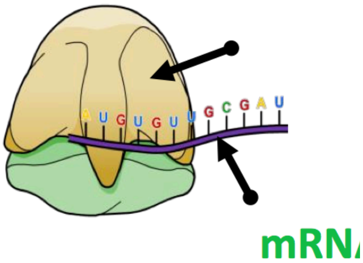
Differences	
DNA	**RNA**
Similarities	

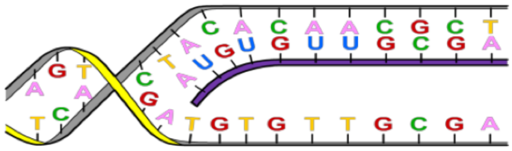
There are three types of RNA. Messenger RNA (mRNA), Ribosomal RNA (rRNA) and Transfer RNA (tRNA). Find out the functions of each type.

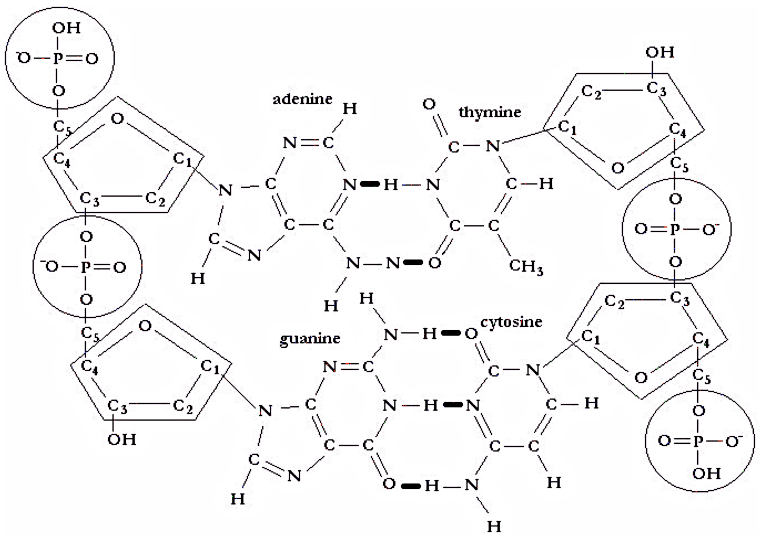
Type of RNA	Function
mRNA	
tRNA	
rRNA	

Identify and label the three types of RNA below:









Organic bases are put into categories. Adenine and guanine are **purine** bases and thymine and cytosine are **pyrimidine** bases.

Look at the diagram on the previous page.
How many carbon ring structures do pyrimidine bases contain?

____

How many carbon ring structures do purine bases contain?

____

This means that **only a pyrimidine paired with a purine** will fit in the space between the sugar phosphate backbones.

Therefore adenine always pairs with _____________

And guanine always pairs with__________________

Looking at the diagram state how many **hydrogen bonds** form between:

Adenine and Thymine ___________________

Guanine and cytosine ____________________

Colour codes the diagram:

Pentose sugar	Blue
Hydrogen bonds	Yellow
Pyrimidines	Green
Purines	Red

DNA quiz

(The letter before each clue is the first letter of the answer - write the answer in the space below each clue)

A. The partner organic base to thymine in DNA. (7)

C. The partner organic base to guanine. (8)

D. Name of the sugar found in DNA. (11)

D. Name given to the double stranded, twisted coil of two DNA molecules. (6) (5)

H. Type of bonds holding together chains of DNA. (8)

N. Charge carried by nucleic acid molecules. (8)

N. DNA and RNA are both types of these. (7) (5)

N. Each DNA molecule is made up of a chain of these. (11)

O. Number of chains of nucleotides making up an RNA molecule. (3)

P. Types of organic base made up of two rings of carbon and nitrogen atoms. (7)

P. Types of organic base made up of a single ring of carbon and nitrogen atoms. (11)

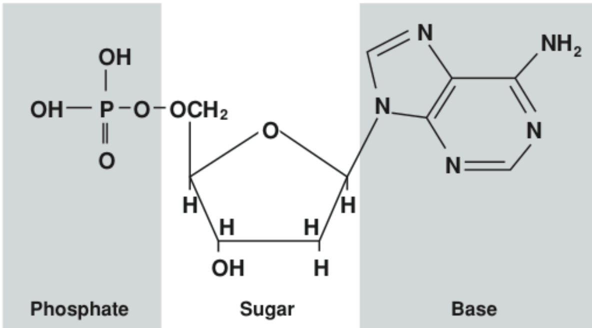
R. Place in the cytoplasm where amino acids are assembled. (9)

U. The partner organic base to adenine in RNA. (6)

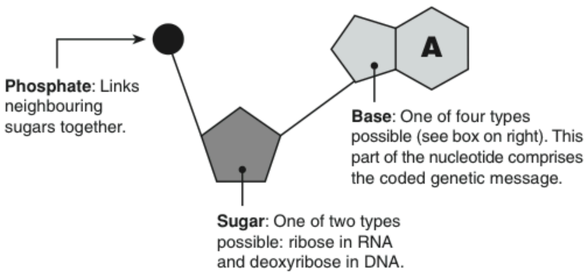
Nucleic Acids

Nucleic acids are a special group of chemicals in cells concerned with the transmission of inherited information. They have the capacity to store the information that controls cellular activity. The central nucleic acid is called **deoxyribonucleic acid** (DNA). DNA is a major component of chromosomes and is found primarily in the nucleus, although a small amount is found in mitochondria and chloroplasts. Other **ribonucleic acids** (RNA) are involved in the 'reading' of the DNA information. All nucleic acids are made up of simple repeating units called **nucleotides**, linked together to form chains or strands, often of great length (see the activity *DNA Molecules*). The strands vary in the sequence of the bases found on each nucleotide. It is this sequence which provides the 'genetic code' for the cell. In addition to nucleic acids, certain nucleotides and their derivatives are also important as suppliers of energy (**ATP**) or as hydrogen ion and electron carriers in respiration and photosynthesis (NAD, NADP, and FAD).

Chemical Structure of a Nucleotide

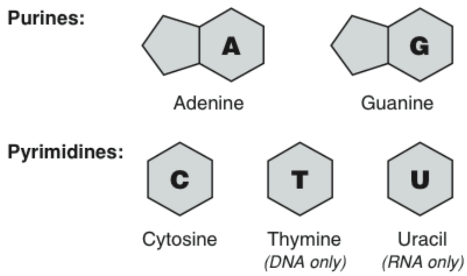


Symbolic Form of a Nucleotide



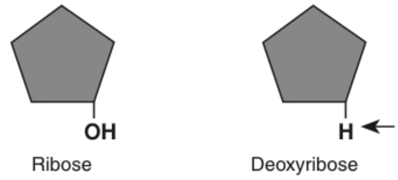
Nucleotides are the building blocks of DNA. Their precise sequence in a DNA molecule provides the genetic instructions for the organism to which it governs. Accidental changes in nucleotide sequences are a cause of mutations, usually harming the organism, but occasionally providing benefits.

Bases



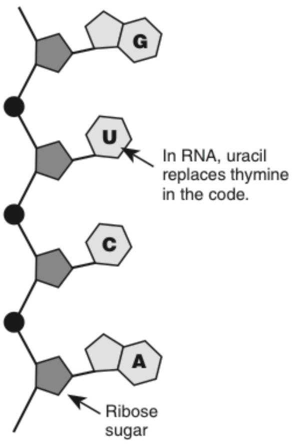
The two-ringed bases above are **purines** and make up the longer bases. The single-ringed bases are **pyrimidines**. Although only one of four kinds of base can be used in a nucleotide, **uracil** is found only in RNA, replacing **thymine**. DNA contains: A, T, G, and C, while RNA contains A, U, G, and C.

Sugars

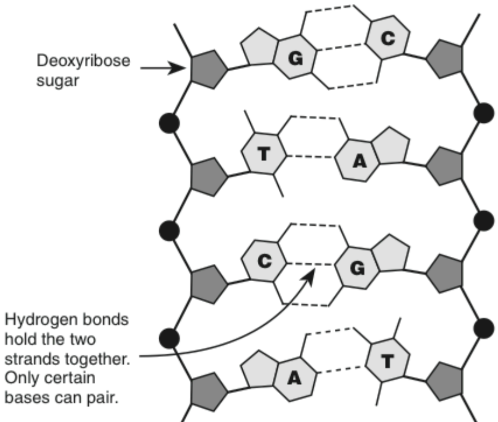


Deoxyribose sugar is found only in DNA. It differs from **ribose** sugar, found in RNA, by the lack of a single oxygen atom (arrowed).

RNA Molecule



DNA Molecule



Symbolic representation

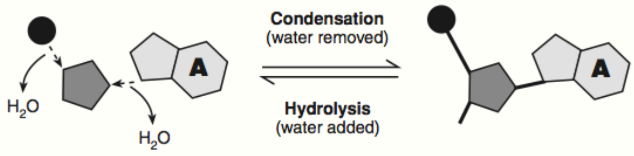
DNA Molecule

Space filling model

Ribonucleic acid (RNA) comprises a *single strand* of nucleotides linked together.

Deoxyribonucleic acid (DNA) comprises a *double strand* of nucleotides linked together. It is shown unwound in the symbolic representation (left). The DNA molecule takes on a twisted, double helix shape as shown in the space filling model on the right.

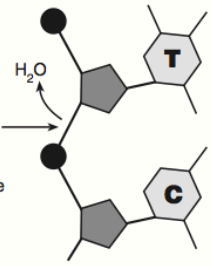
Formation of a nucleotide



A nucleotide is formed when phosphoric acid and a base are chemically bonded to a sugar molecule. In both cases, water is given off, and they are therefore condensation reactions.

Formation of a dinucleotide

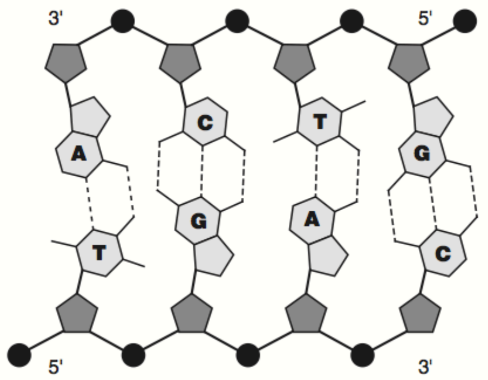
Two nucleotides are linked together by a condensation reaction between the phosphate of one nucleotide and the sugar of another.



Double-Stranded DNA

The **double-helix** structure of DNA is like a ladder twisted into a corkscrew shape around its longitudinal axis. It is 'unwound' here to show the relationships between the bases.

- The way the correct pairs of bases are attracted to each other to form hydrogen bonds is determined by the number of bonds they can form and the shape (length) of the base.
- The **template strand** the side of the DNA molecule that stores the information that is transcribed into mRNA. The template strand is also called the **antisense strand**.
- The other side (often called the **coding strand**) has the same nucleotide sequence as the mRNA except that T in DNA substitutes for U in mRNA. The coding strand is also called the **sense strand**.



1. The diagram above depicts a double-stranded DNA molecule. Label the following parts on the diagram:
   (a) **Sugar** (deoxyribose)
   (b) **Phosphate**
   (c) **Hydrogen bonds** (between bases)
   (d) **Purine** bases
   (e) **Pyrimidine** bases

2. (a) Explain the **base-pairing rule** that applies in double-stranded DNA: ____

   ____

   (b) Explain how this differs in mRNA: ____

   (c) Describe the purpose of the hydrogen bonds in double-stranded DNA: ______________________________________

   ____

3. Describe the functional role of nucleotides: ____

   ____

4. Distinguish between the **template strand** and **coding strand** of DNA, identifying the functional role of each:

   ____

   ____

   ____

5. Complete the following table summarising the differences between DNA and RNA molecules:

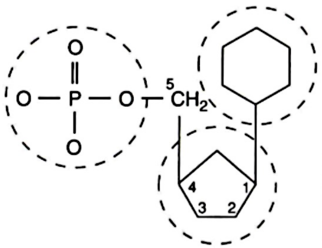
	DNA	RNA
Sugar present		
Bases present		
Number of strands		
Relative length		

DNA (deoxyribonucleic acid) is the genetic material

The Watson–Crick model for DNA suggests that the molecule is a double helix of two complementary, polynucleotide chains.

Nucleotides are the subunits of nucleic acids, including DNA. Each of these subunits is made up of:

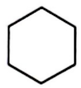
AN ORGANIC (NITROGENOUS) BASE + A PENTOSE SUGAR + A PHOSPHATE GROUP (PHOSPHORIC ACID)



Note that the phosphate group is bonded to the C_5 atom of the pentose sugar.

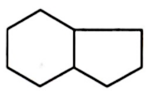
There are **four different nucleotides** in a DNA molecule; they differ only in the organic (nitrogen) base present.

There are two different **pyrimidine (single ring)** bases, called **cytosine (C)** and **thymine (T)**



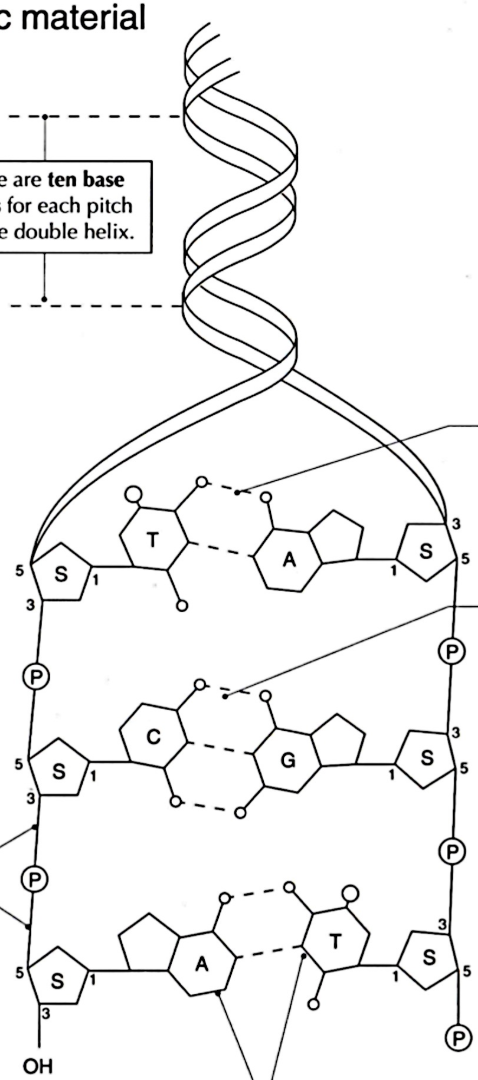
and

two different **purine (double ring)** bases called **adenine (A)** and **guanine (G)**.



The different dimensions of the purine and pyrimidine bases is extremely important in the formation of the double-stranded DNA molecule.

There are **ten base pairs** for each pitch of the double helix.



Nucleotides are linked to form a **polynucleotide** by the formation of 3′ 5′ **phosphodiester links** (phosphate bridges) in which a phosphate group forms a bridge between the C_3 of one sugar molecule and the C_5 of the next sugar molecule.

The chains are complementary: because of base pairing, the base sequence on one of the chains automatically dictates the base sequence on the other.

Requirements for a genetic material

- Accurate replication during cell growth and duplication.
- Stable structure to reduce the risk of mutation.
- Must have the potential to carry biological information.
- It must offer a way of transferring information into cell characteristics.

Base pairing in DNA was proposed to explain how two polynucleotide chains could be held together by hydrogen bonds. To accommodate the measured dimensions of the molecule each base pair comprises **one purine - one pyrimidine**.

The double helix is most stable, that is the greatest number of hydrogen bonds is formed, when the base pairs

A ::::::: T (two hydrogen bonds)

and G ::::::: C (three hydrogen bonds)

are formed. These are **complementary base pairs**.

Note that in order to form and maintain this number of ○ hydrogen bonds the nucleotides are inverted with respect to one another so that the phosphate groups (here shown as P) face in **opposite directions**.

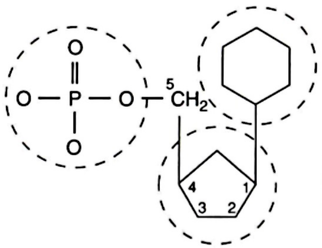
DNA structure is suited to function

- It is very stable: nucleotides are linked by **covalent** bonds.
- It carries coded information: the **order of the nucleotide bases** can be used to control production of other molecules.
- It can be replicated: **specific base pairing** means that DNA can be copied when cells divide.
- It is compact: **folding** of the molecule means a great deal of information can be packed into a small volume.

DNA (deoxyribonucleic acid) is the genetic material

The Watson–Crick model for DNA suggests that the molecule is a double helix of two complementary, polynucleotide chains.

Nucleotides are the subunits of nucleic acids, including DNA. Each of these subunits is made up of:



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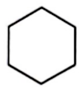
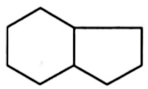


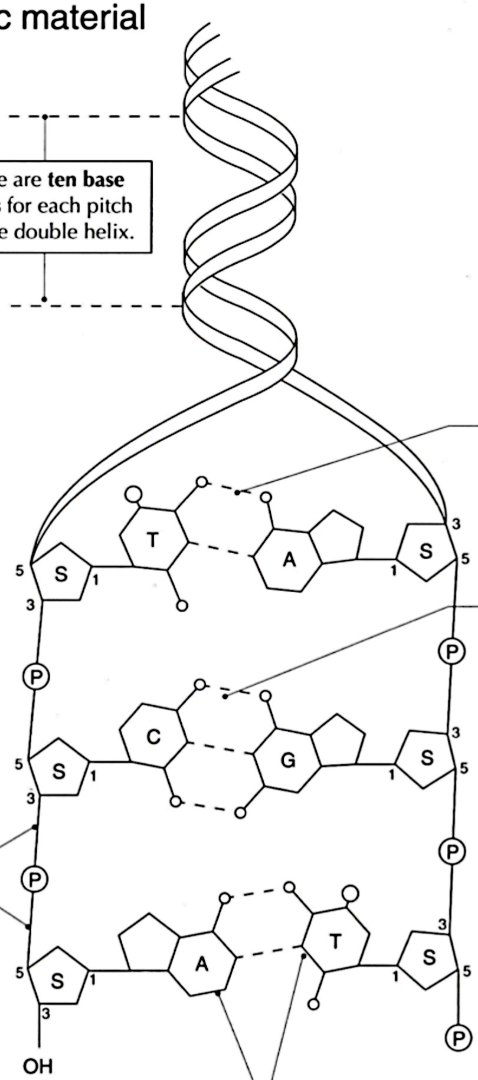
and

two different **purine (double ring)** bases called **adenine (A)** and **guanine (G)**.



The different dimensions of the purine and pyrimidine bases is extremely important in the formation of the double-stranded DNA molecule.

There are **ten base pairs** for each pitch of the double helix.



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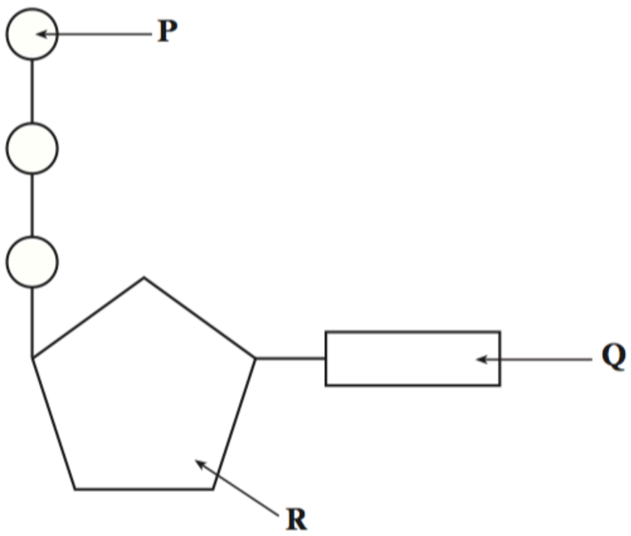
Past Paper Practice:

1.

The diagram below represents the structure of ATP.



(a) Name the parts of the molecule **P**, **Q** and **R**. [3]

P ....

Q ....

R ....

(b) (i) ATP is often described as the 'universal energy currency'.
Explain why it is described in this way. [2]

....

....

....

....

(ii) Give **three** advantages of ATP for its function as a source of energy. [3]

1 ....

....

2 ....

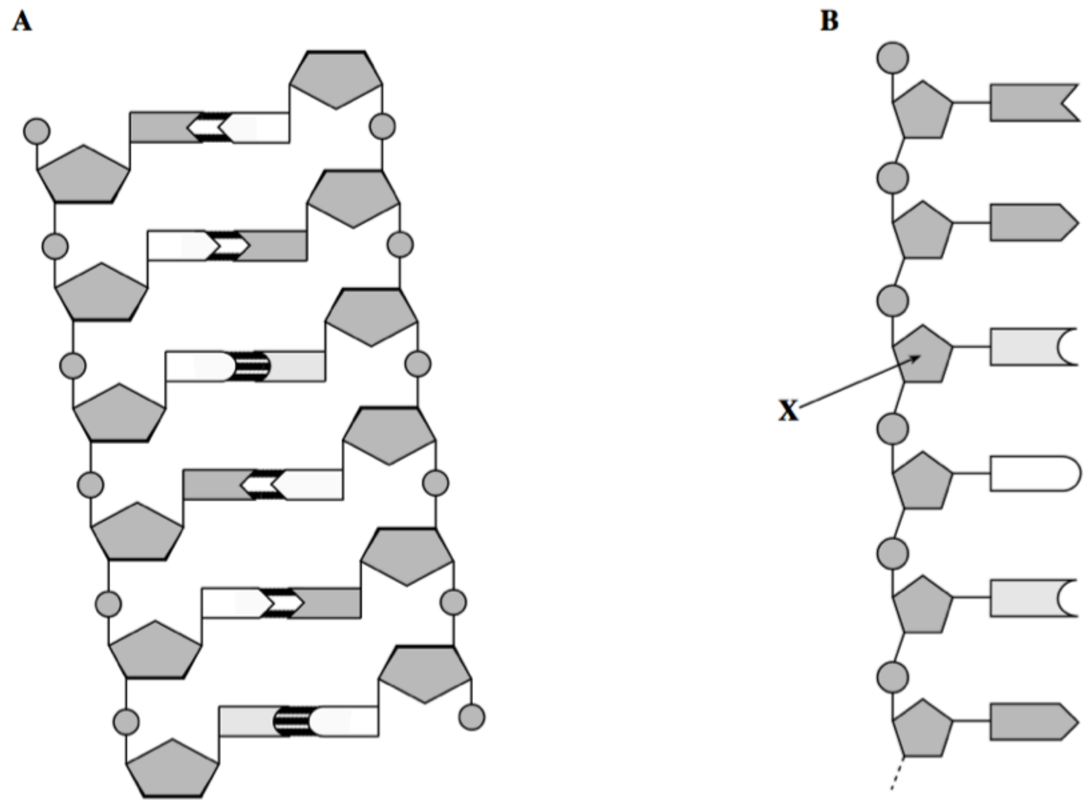
....

3 ....

....

2.

The diagrams below represent two biological molecules.



(a) (i) Name molecules **A** and **B**. [1]

A ....

B ....

(ii) Name **X**. [1]

....

(iii) Where in the cell would you find molecule **A**? [1]

....

(iv) Name the bond that holds the two strands together in **A**. [1]

....

(v) Give **one other** structural difference, not illustrated in the diagram, between the two molecules **A** and **B**. [1]

....

....

(b) Erwin Chargaff recognised that there were four types of bases in the nucleic acid found in the nucleus. The table below shows the results of his experimental work.

Source of nuclear material	*% adenine*	*% guanine*	*% cytosine*	*% thymine*
wheat	27.3	22.7	22.8	27.1
broad bean	29.7	20.6	20.1	29.6
salmon	29.7	20.8	20.4	29.1
bull	28.6	22.2	22.0	27.2
human	30.9	19.9	19.8	29.4

Source: Chargaff, E. (et al.) 1953, *Nature,* London, no. 172, p.289

(i) What conclusions did Chargaff draw from this data about the pairing of bases in the nucleic acids of various species? [1]

....

....

(ii) Using the data from the table above, explain how he came to his conclusion. [1]

....

....

(iii) What category of bases are adenine and guanine? [1]

....

(Total 8 marks)